Faculty of Engineering

CREEP BEHAVIOUR OF OIL PALM EMPTY FRUIT BUNCH (EFB) FIBRE - POLYESTER COMPOSITE

Verawaty Binti Hj Ismail

Bachelor of Engineering with Honours
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VERAWATY BINTI HJ ISMAIL

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Judul: CREEP BEHAVIOUR OF OIL PALM EMPTY FRUIT BUNCH (EFB) FIBRE-POLYESTER COMPOSITE

SESI PENGAJIAN: 2001 – 2005

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Matric No.	: **7239**

has been read and approved by;

Mahshuri bt. Yusof
(Supervisor)

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ABSTRACT

Oil palm empty fruit bunch (EFB) fibre reinforced polyester composites of 40% and 60% fibre content have been produced. An experimental study was taken to establish the creep behaviour of EFB fibre-polyester composite in compression made under room temperature. Two experimental parameters were selected which are load and fibre content. Results exhibit that the creep rate increases with increasing load, which also means creep resistance decreases at higher load. It was also found that the EFB fibre content has great effect on creep resistance, which decreased with fibre content. This is applicable only on power-law creep, which satisfies the secondary creep rate.

ABSTRAK

Bahan komposit berasaskan poliester yang mengandungi 40% dan 60% gentian dari tandan buah kelapa sawit telah dihasilkan. Uji kaji telah dijalankan dalam mod mampatan untuk menunjukkan sifat rayapan bagi bahan komposit berasaskan poliester daripada gentian tersebut pada suhu bilik. Dua parameter uji kaji dipilih iaitu beban dan kandungan gentian. Keputusan menunjukkan kadar rayapan meningkat dengan peningkatan beban yang bermaksud rintangan rayapan mengurang pada bebanan yang tinggi. Kandungan gentian dari tandan buah kelapa sawit juga didapati memberi kesan ke atas rintangan rayapan dimana rintangan rayapan berkurangan dengan peningkatan kandungan gentian. Ini cuma berlaku ke atas rayapan 'power-law' yang menepati keadaan pada rayapan sekunder.

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CHAPTER 1

INTRODUCTION

1.1 Background

Oil palm, also known in scientific name as *Elais guineensis* is originated from West Africa and introduced to Malaysia in 1987 as an ornamental plant (PORLA/Oil World Report, 2002). It was grown commercially since 1917 as an agricultural crop for its versatility in application of oil and fat. From 55,000 hectares back in 1960, oil palm crop area had been expanded to 2.82 million hectares in 1997 covering half of cultivated area, making oil palm crop the leading agricultural industry in Malaysia (Gurmit *et.al*, 1999).

Figure 1.1: The Oil Palm, *Elais guineensis* Taken at FELCRA Sdn Bhd Plantation

The refining of crude palm oil commenced in early 70s in conjunction to the Malaysian Government call towards industrialization. Oil palm is being employed in numerous food and non-food application, such as cooking oil, margarines, soap, oleochemicals and other products. With the emergence of oil palm mill, Malaysia is presently the world's largest producer and exporter of palm oil. According to Gurmit *et. al.* (1999), the country had produced 9.07 tonnes of crude palm oil, exporting the bulk of its products and earning about RM12.9 billion in profits.

This research had addressed the oil palm crop waste as a potential fibre for particle reinforced composite. This is due to the crop agricultural and industrial waste that can be easily found in all over Malaysia, including Sarawak. Moreover, the technology of natural fibre-polymer composite had received an increasing industrial interest in many fields such as construction, building and automotive composites.

1.2 Oil Palm Waste

Oil palm continuous cultivation and refining had been producing a great number of lignocellulose sources. Identified fibre sources from the crop are the trunks, fronds and empty fruit bunches, which are obtained from two locations. The trunks and fronds from oil palm plantations and empty fruit bunches are obtained from the oil palm mill.

From the plantation, oil palm trunks are only available when the economic life-span of the palm has reached its replanting cycle. According to Chan (1999), the average age of replanting is about 25 years. Oil palm trees will also be chopped down after it reaches over 13 m height and the decreasing of annual yield fruit bunches below 10-12 tons/hectares. As for the oil palm fronds, they are obtained either during regular harvest and pruning, or during replanting time.

In palm oil milling, when the Fresh Fruit Bunch (FFB) are processed, the end products are crude palm oil and kernel, while the by-products are empty fruit bunches (EFB), fibre and effluent. Empty fruit bunches are obtained at the first stage of the milling process. When the FFB are sterilized, sterilizer condensate is produced and then after threshing, the by-products consist of stalks with empty spikelets called empty fruit bunches are produced.

In this work, strands from empty fruit bunches are preferred as it can be obtained during regular harvest and oil palm processing. The most available is the EFB with an annual production of 3 million tones (dry weight) (Husin *et al.*,1985). Utilization of EFB in particleboard, medium density fibre boards and pulp had shown the potential of EFB particle fibres to produce composite with acceptable properties.

1.3 Scope and Objective

The aim of this work is to investigate the creep behaviour of oil palm empty fruit bunch (EFB)-polyester composite. The effects of applying various load and fibre contents on creep behaviour of material will also be investigated in this study.

To achieve these objectives, the fibre from Empty Fruit Bunch (EFB) are extracted and processed prior to composite panel fabrication. Then, the fibres are mixed with resin in two different fibre volume fractions (40% and 60%) and hot stamped to obtain a composite panel. Then the panels are cured, cut and tabbed before performing compressive creep tests.

CHAPTER 2

LITERATURE REVIEW

2.1 Creep Definition

Creep as defined by Timings (2000), is a gradual extension of material under a constant applied load over prolonged period of time, particularly at elevated temperature. Whereas, Mallick (1993) had defined creep as the increase in strain with time at a constant stress level. As for Higgins (1994), creep describes the continuing slow deformation with passage of time in materials subjected to steady persistent stress.

However, in simpler words, Hibbeler (1997) explained that creep took place when a material has to support an amount of static load for a very long period of time, it may continue to deform until as sudden fracture occurs or its usefulness is impaired. This time-dependant permanent deformation had exhibit plastic strain all through the particular period and occurs even though acting load is below the yield stress of the material.

2.1.1 Creep Behavior

The behavior of creep on a strain versus time graph is shown in Figure 2.1. A typical creep curve demonstrates that there are primary, secondary and tertiary creeps. The primary or transient creep begins at a rapid rate, which then decreases with time as strain hardening sets in.

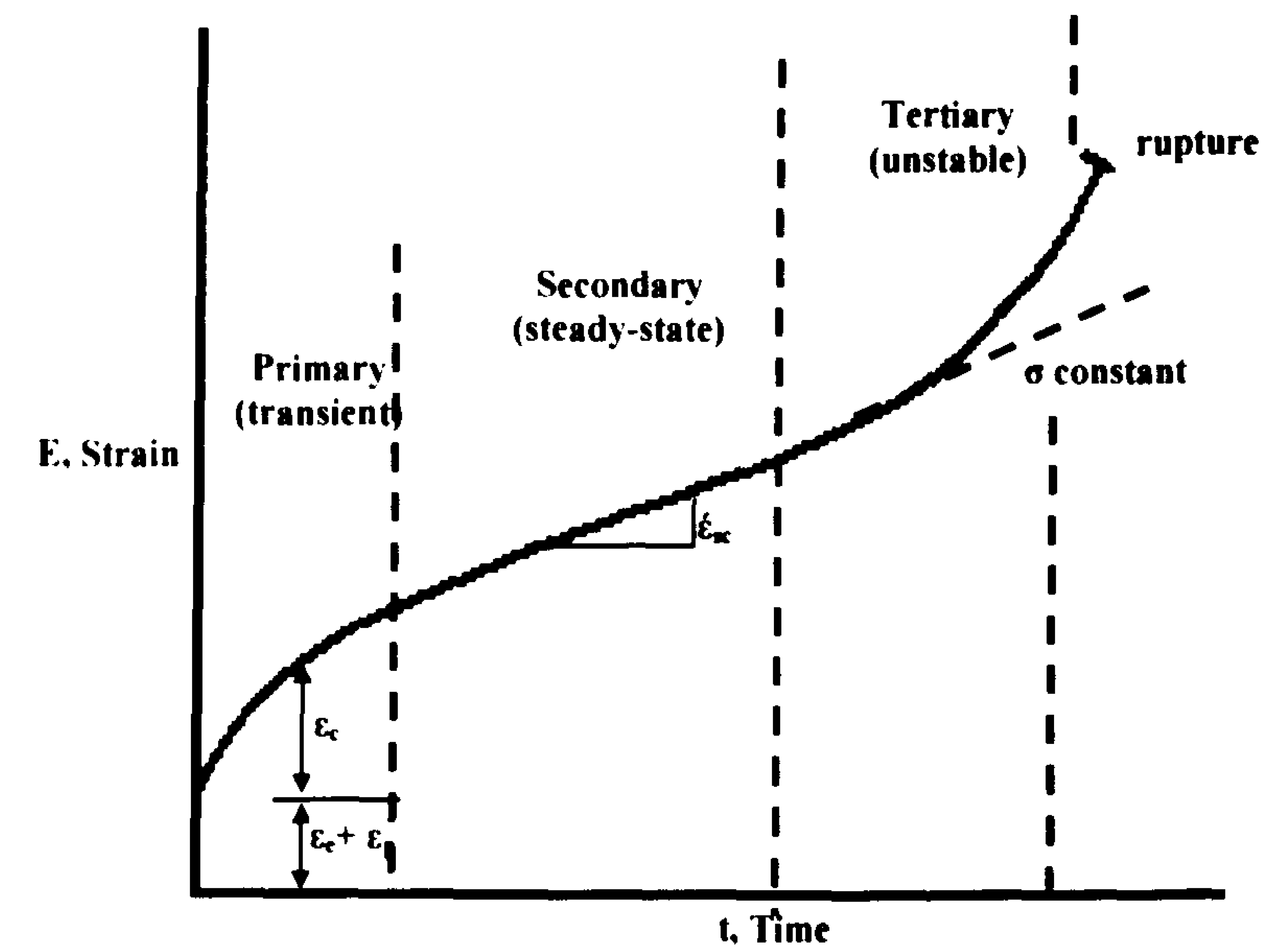


Figure 2.1: Strain Vs Time Behavior During Creep Under Constant Load (Dowling, 1993)

This is followed by secondary or steady-state creep, in which the rate of strain is uniform and at its lowest value. According to Timings (2000), during this stage, the work hardening effect of the deformation increases but it is balanced by the recovery process of the material. The strain rate, $\dot{\varepsilon} = d\varepsilon/dt$, where $\dot{\varepsilon}$ is a constant for a given set of conditions of temperature and stress and is equivalent to the slope of the steady state curve in the graph. $\dot{\varepsilon}$ will vary with both temperature and applied stress since recovery processes are both temperature and stress dependant.

Temperature dependence is a consequence of the diffusion of dislocations caused by thermal activation and can therefore be presented by an Arrhenius-type equation:

$$\dot{\varepsilon} = A(\sigma)^n e^{(-Q/RT)} \quad [2.1]$$

where:

$d\varepsilon/dt$ = secondary creep rate, A = constant, T = absolute temperature, Q = activation energy for creep, and R = universal gas constant

Secondary creep also increases with stress, the relationship being generally expressed by:

$$\dot{\varepsilon} = \beta\sigma^n \quad [2.2]$$

where β and n are constants, n usually varying from 3 and 8 for metals and between 1 and 2 for polymer materials. Combining equations [2.1] and [2.2], gives:

$$\dot{\varepsilon} = A\sigma^n e^{(-Q/RT)} \quad [2.3]$$

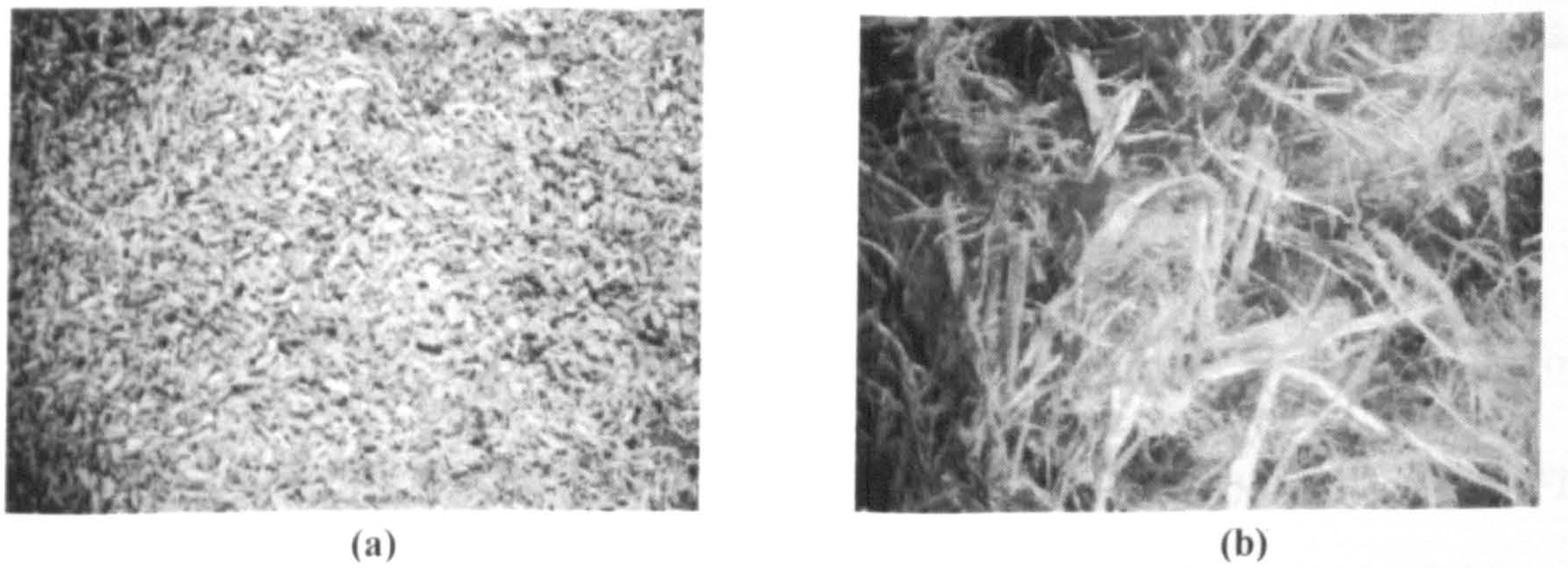
The value of $\dot{\varepsilon}$ is at first relatively high, however, it decreases and often becomes approximately constant, at which point the primary or transient stage of creep is ending and the beginning of secondary stage. At the secondary stage (steady state), the slope is linear within longer period of time. The end of the secondary stage, $\dot{\varepsilon}$ increases in an unstable manner as rupture failure approaches, with this part being called tertiary stage.

Finally, tertiary creep began to appear at the grain boundaries as the barriers to dislocation movement become too great for thermal agitation and the applied stress to overcome. These micro-cracks result in a rapid reduction in cross-section (necking) leading to a rapid increase in creep rate and fracture.

2.2 Creep Characteristics in Natural Fibre-Polymer Composites (Wood Fibre-Polypropylene Composites)

The technology of wood fibre-polymer composites had gained an increasing interest in material engineering field. Similar to that of EFB fibre, wood fibre is a natural structure made of cellulose fibres, which have the potential of making low cost composite materials, especially in developing tropical countries such as Malaysia. Beldzki and Faruk (2003) had conducted the research to determine the creep and impact properties of wood fibre-polypropylene composites.

Creep is one characteristic of wood fibre reinforced polymer composites that has resulted in poor performance in certain applications (Bledzki and Faruk, 2003). As both wood fibre and EFB fibre contains lignocellulosic properties, similarity in creep behavior in EFB fibre-polymer composite with that of wood fibre composite is more likely to be achieved. The research by Bledzki and Faruk (2003) is conducted on wood fibre-polypropylene composites. The wood fibres used are of the hard and long type of fibres (Figure 2.2), treated with compatibiliser (MAH-PP) to increase interfacial adhesion with the matrix.



(a) (b)

Figure 2.2: Micrograph of Hard Wood Fibre (a) and Long Wood Fibre (b) with 12.5:1 magnification (Bledzki and Faruk, 2003)

Investigation on short-term creep behavior was conducted on the composites under three parameters:

- *Addition of the compatibiliser* – Creep test performed on both treated and untreated hard wood fibre composites with 40 wt.% wood fibre content at 60°C.
- *Temperature* – Creep investigated on untreated hard wood fibre composites with wood fibre content (40 wt.%) at room temperature, 40°C and 60°C.
- *Wood-fibre content* – Creep test conducted on composites containing 40 wt.%, 50 wt.% and 60 wt.% for treated fibre at 40°C for both type of wood fibres.

For the addition of compatibiliser, it was reported that treated specimens have higher creep modulus than untreated specimen. This proved that the MAH-PP treatment usually improves fibre dispersion in matrix resins and facilitates the interfacial adhesion between the fibres and polymer matrix (Bledzki and Faruk, 2003). At different temperatures, all specimens demonstrate creep modulus decrease with time and temperature. Thus, Bledzki and Faruk (2003) believed that higher temperature normally reduce the creep modulus of matrix-dominant composites, as the matrix (polypropylene) is typically softened by elevated temperature.

Fibre content is also found to be a major influence in creep characteristic of the composites. For both type of wood fibre (hard and long wood fibre), the creep modulus demonstrated an increment with the increase of fibre content. Bledzki and Faruk (2003) also found that long wood fibre –PP composites shows better creep modulus, which means wood fibre length also plays an important role into interaction between wood fibre and polypropylene matrix.

Overall, the study gives the idea of creep characteristics of an example of cellulose based natural fibre. Important points that can be drawn from the research are that three main parameters affecting creep are the compatibiliser treatment, temperature and fibre content of the natural fibre-polymer composites. Hence, this gives a rough thoughts of similar creep characteristic will be exhibited by oil palm EFB fibre-polymer composite. Nonetheless, the investigation is yet to be determined.

2.3 Creep Parameter

Creep behavior of polymer and polymeric composites are generally affected mainly by temperature and stress level. Unreinforced polymers exhibit large creep strains at room temperature and at low stress level but creep phenomenon will become critical at elevated temperature or high stress level (Mallick, 1993). However, reinforced polymers have a few more parameters that must be taken into account. The main parameters affecting creep properties of natural fibre reinforced are including the fibre content, chemical treatment on fibre to improve the fibre-matrix bonding and moisture content of composites.

In this section, main parameters will be discussed are the temperature, fibre content, fibre-matrix bonding and moisture effect of polymeric composites.

2.3.1 Temperature

The influence of temperature on mechanical properties is usually evaluated by noting changes in elastic parameters, strength, creep or stress relaxation properties, or the combination of the mentioned. Generally, increasing temperature accelerates creep at all stages and also increases deformation at failure and thus decrease the creep modulus and creep strength. The data shown in Figure 2.3, which reflect a linear decline of modulus of elasticity with increasing temperature, are indicated by the trends exhibited by many natural fibre composites over restricted temperature ranges.

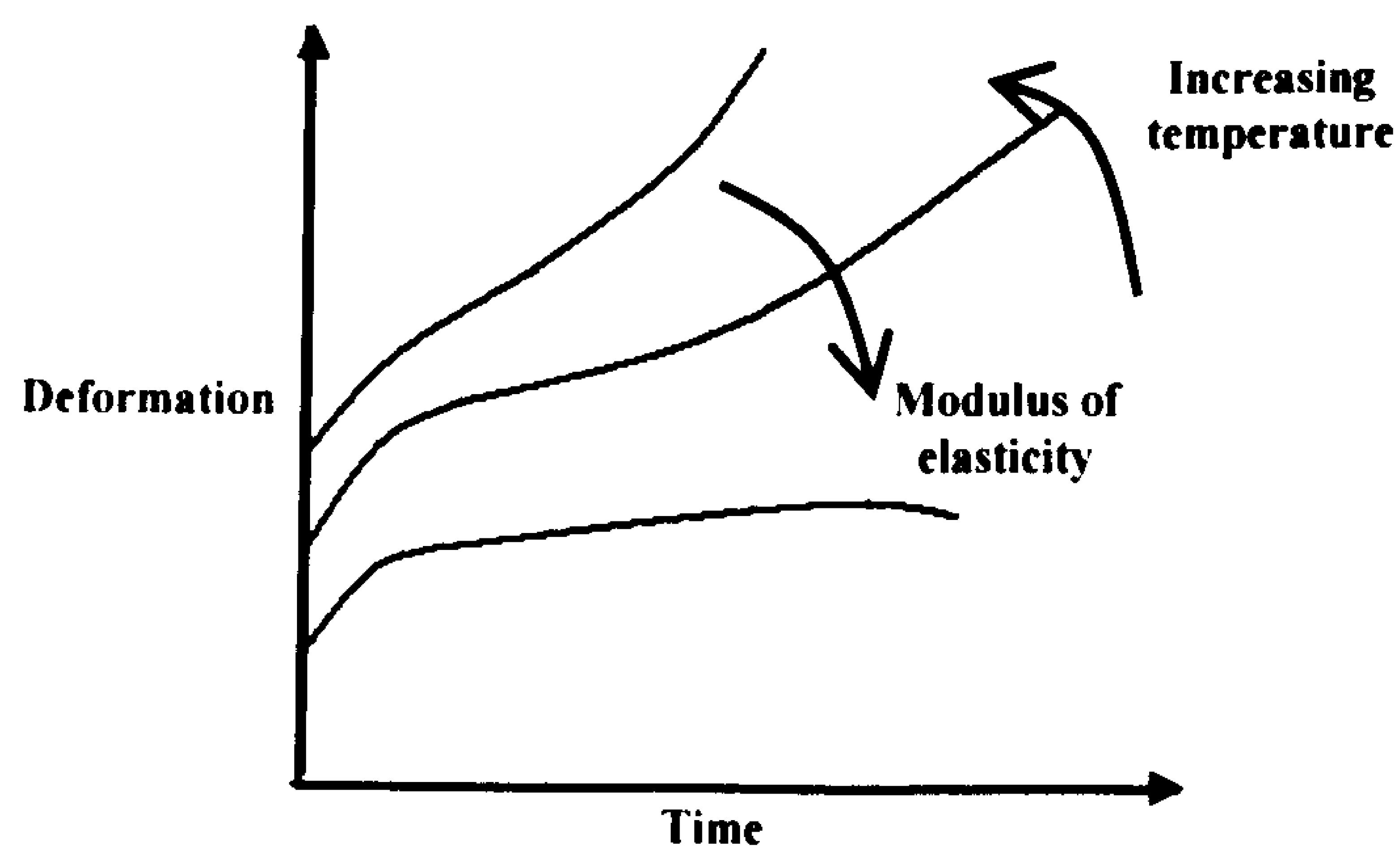


Figure 2.3: Effect of Temperature on Creep Behavior of Wood. (Bodig and Jayne, 1982)

Joseph *et. al.* (1994) on investigating the ageing of sisal fibre reinforced thermoplastic composite at 80°C, found that the specimens showed a general tendency to increase their strength up to a limited time of exposure (1 day). This may be due to the fact that the fibre/matrix adhesion will be increased due to softening of polyethylene matrix. Joseph *et. al.* (1994) had reported that short-time ageing at high temperature improves the mechanical properties of thermoplastics. However, deterioration of strength was observed after an exposure of 1 day at an elevated temperature (80°C). It is suspected that the loss of fibre strength is due to decomposition present in the sisal fibre surface.

As discussed earlier, the study on wood fibre-polypropylene creep showed similar trends of behavior with that of ageing on sisal reinforced thermoplastics research. A decreasing creep modulus exhibited at higher temperature. Bledzki and Faruk (2003) found that creep modulus of wood fibre-polypropylene composites was around 1800 MPa after 180 min at 60°C, which was nearly 65% lower than that of room temperature (23°C). Figure 2.4 illustrates experimental result of the research.

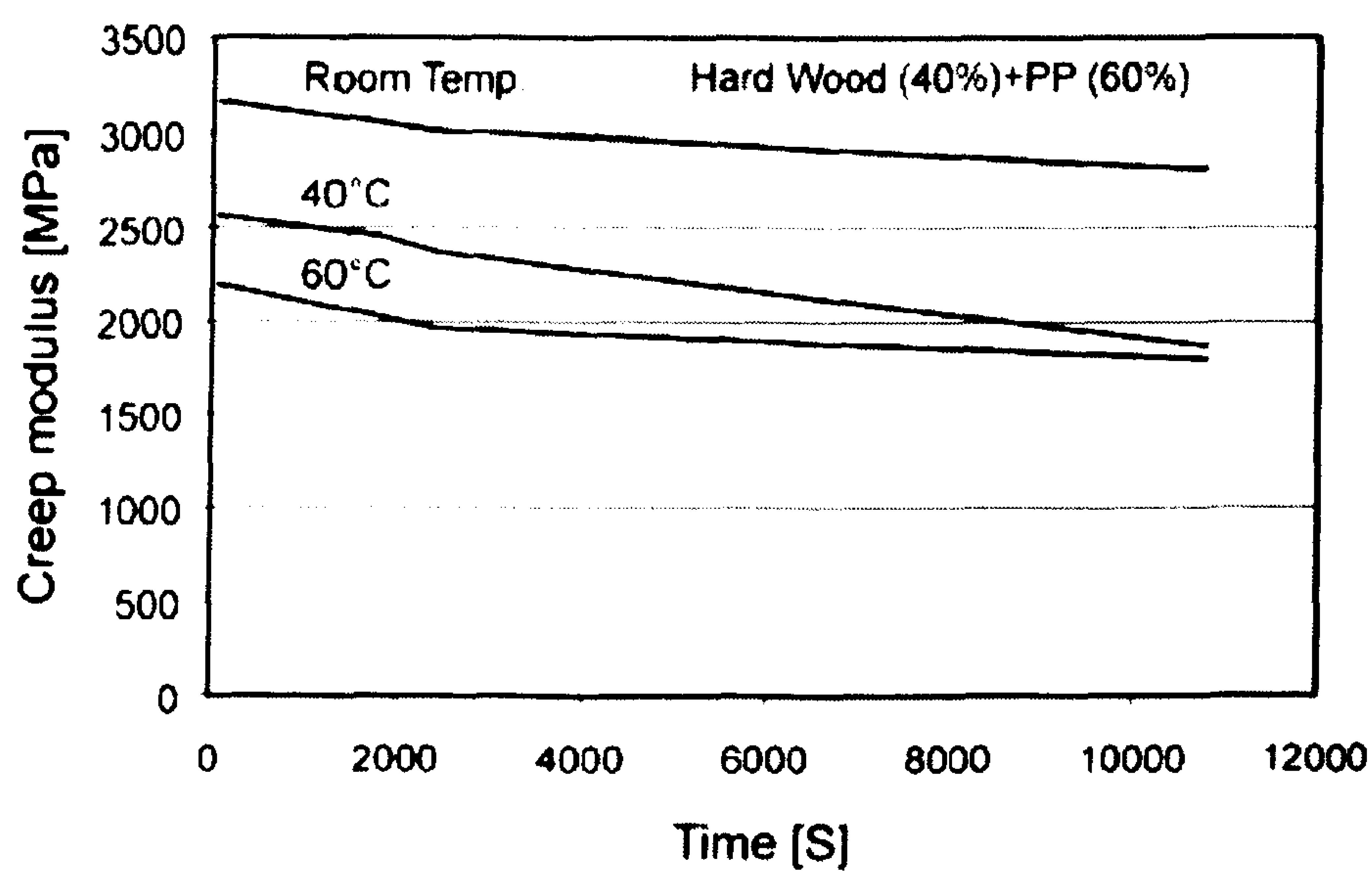


Figure 2.4: Creep Modulus of Hard Wood Fibre-PP Composites at Different Temperatures (Bledzki and Faruk, 2003)